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CLASSIFICATION

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CANADIAN PATENT

LINER EXPANDER

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PRIORITY DATE

No. OF CLAIMS

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial cectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inverdly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 35 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 45, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

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The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft lo.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein $P_{\mathbf{c}}$ is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

- 1. A device for expanding a metallic liner inside a conduit which device comprises a shaft element, an expanding die member attached to said shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against said liner by a substantially constant force.
 - 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
 2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a sleeve-like element connected to said movable bearing plate member and slidably positioned on said shaft and a member connected to said shaft to limit the travel of said sleeve-like element.
 - 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said chaft.
 - 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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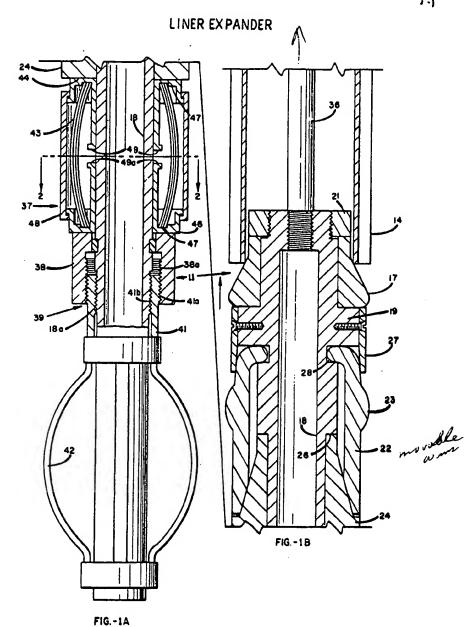
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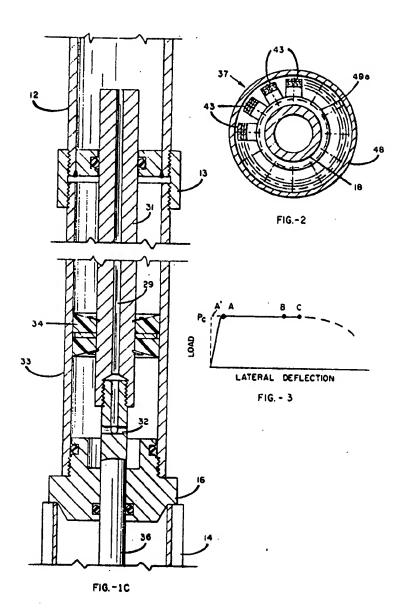
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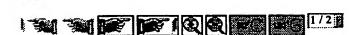
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2. In a device for installing an extended mobilic liner in a conduct therein an expanding die is moved through a liner positional in said southers to expland said liners a cylinerical graft almost, an expending die sender attached to said shaft, said die sender commising a plausiffy of ans member discount acute described and being privatable integrally therefore to contact still liner, a come member shidally positioned on cale shaft between end shaft and mad and members to urpo said arm members consardly frue said shaft, and a constant force spring number positioned on cald staft to contact said come member and a constant force spring number positioned on cald staft to contact said come member in contact with said are members, whereby said agm tembers are urged outwardly by a substantially constant furce.

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- . A. the device of Claim 3 wherein each compression process comprises a \$100pm; Alanda survey consensing mile apring master and said shaft.
- 5. The device of Chair 3 wherein said shop means comprises a also re-like element commented to said sovehile bearing plane member and missair positioned on raid short and a surface consequed to said shaft to limit the travel of said also re-like element.
- 6. The device of thata 3 warrais soid columns have a mechangular areas-soution, the width being greater than the thickness, and bening the wider free moved to the disenter of said shaft.
- 7. A device for installing on expended astallis liner to a comist which comprises a cylindrical shaft classical to accoming the senter mounted on said shall, said the sember comprising a plantity of are sombare disposed direnthreshially around the embedde of said shaft and bedse pleotable outmaily therefrom to contact the liner; a scaled arguming master slidebly positioned on said sheft between said sheft and maid are exchance to surpr said are members cuttandly from suid shaft; a plurelity of element columns, each bewing a long reutangular cross-section and disposed sireathmentially shout suid chaft; an upper bearing plate member and a lower bearing plate suster, such slidelity positioned on said shaft and outdeoning apposite onto of said me; limiting alseres ublacked to each of still hearing plate members and alidably positioned an said statts a shoulder number on said shafts a differential score elevent connecting will shoulder and said shaft to apply skiing lock to said solumny suid thoulear being consequents with the soled to emid lessor bearing plate mester, whereby the arial traval of maid bearing plate numbers is limited; said column weathers breassitting their buckling look to exid arm rembers to urgs said arm greaters enteredly with a substantially constant force.

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My invention will be better understood by reference to the following description and the accompanying drawings wherein

Figure 1A, 18 and 1C, tabes together, convilute a pertial sectional view of a preferred embediment of a liner expending tool according to the present investion; and

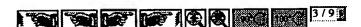




Figure 2 to a sectional view of the apparatus of Figure 1A taken at

Figure) is a typical plot of applied lock versus Deflection for the constent force spring device of the invention.

Referring to the drawings, Figure 14 is the lotton portion of a liner expending tool for one in installing a metallic liner to a well, while Figure 15 Libertrotos the middle section of such a tool and Figure 10 represents the upper section of the tool. The expending tool il is attached to ctanters well taking 18 by compling 15 cost, typically, may be lowered from the surface through a well easing (not shown) to a point in the suring at which it is desired to install a metallic liner. Defore inserting the tool into the well, an elongated vertically corrugated liner in Cabricated from mild steel, or other suitable milesble meterial, is placed on the tool. The corrupted liner is secured in position by sentant at its upper end with a cylindrical shoulder number 16 and, st the lower and by contact with a first-stage espanding die 17 in the form of a trumosted circular cone stdah serves as a firsteding 410 in the server bareinefter described. The expanding die is fixedly stituded to a controlly located, elemented cylindrical hollow short ld which forms a portion of the body of the tool. As shown, the expending \$40 17 is half in place between a lower shoulder 19 and coller 21 threaded onto the energy. A plurality or morphic arms 89, preservably provided with contentally cularged portions 85 sear the top; wie disposed in the form of a sylindar around shaft 18. Too enlarged purbless of the arms 23 upon being moved outvarily emises the liner to perform the final step of aspending the correspond liner into a substantially systamical shape. The are seafers 22 are pivotally etteched to the sheft so as to be movehlo outcomely from the sheft by a tapared expending member 26 slikebly positioned on the short to earws as a second-stage expender. The equience of the measure th, as shown, moves specially along the shaft to sugage with the area and move them outwardly. Adventageously, the 30 inside surfaces of the area 62 and the outside carface of expanding member 25 fore setting sections, typically colegonal is shape. The expension of the arm members is controlled by the position of the member 20 rhich moves upwardly



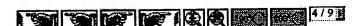


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forces between the tool and the liner and the pressure emerted definet the oneing are maintained at pressurement safe levels. The constant force spring marker easures that the sentest pressure between the liner foundary portion 20 of the arms 22 is great enough to provide the derived deformation of the odd-

The equators force spring standar 77 is alignity sounted on the shall be end hald between the expending alsocat 20 and a cylindrical lower checker senter 36 forcing a portion of a differential serve alsocat 39 which because the local amount of the standar 37 to chart member 18. The differential serve alsocat comprises shall member 16 as the certific of which are such mate threads 18a, the lower absolder number 30 provided with female threads 30 and thinkle member 31 provided with threads and the inside, respectively, to employ with threads and and \$10 on the certific and the inside. The two case of threads are source, such as square, solified equark, or fonce threads, to withertand very high loads and differ in pitch so that shoulder 35 is seven appearily on the chart 10 when the shall is severed relative to thinkle \$1. The shoulder 30 is secured to the shall 10 by splines 55 so that it can alide longitudinally, but it is not tree to rotate on the shalt. Finally attached to the lower set of the thinkle is a friction scaler, such as but springs 49, a hydraulically equated friction pai, or other such devise for frictionally emploing with the inside mill of the accipit to occur the thinkle against the object, and the plant, or land, or strends 10a is slightly greater than these of threads 30a, with the pitch, or land, or strends 10a is slightly greater than these of threads 30a, with the pitch retain being alows to unity. In this success, clock-vice recolution of the shart relative to the thinkle success shoulder success \$5 to advance upwerd alightly and a compression load is americal upwardly on apring alassent 37 to unsee butting. For example, one retired and extends on a shart approximately 1.7-inch outside dissector and five and illustrate threads such a charter threads on a shart approximately 1.7-inch outside dissector and five and illustrate threads on a shart approximately 1.7-inch outside dissector and five and illustrate.



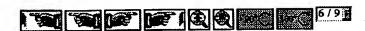


Descript force spring element 37 comprises unions element by, elementageously serviring or a plurality of elements of classification of the salars being plate number by to to contact with the apper ends of the salars and is elifably positioned or whart if to trements the force of the ageing longitudinally against the bottom and of expendes sender SA. Lower bearing plate number 16 contacts the lower sends of the columns and 18 moved squardly along the shart by lengthedinal normals of the selment SD on a result of revolving differential server element 39. Greenes 37 are provided in much or the bearing plates, to form an apper rate and a lower race, into which the sents of the solmes are inserted. These greenes may be shaped to contain with the shape of the column such if sandred. A cover 16 any be employed to another foreign antiter from the spring mechanism and to protect

A means for limiting the deflection of the columns to required. Although the column element functions in a buckled condition, application of . erosealwe sempressive load thereto would seeme total failure or repture of the a. Therefore, a pair of stope by end bye are provided for this purpose. m, the stope ere rigidly commerced to the bearing plates, and, in of comprise upper and lower limiting eleanes positioned on the shaff to slide longitudinally thereon. The unde of the stops may nove toward, or evan from, each other as the load in the spring number worked. LINER slaves age irtal from noting does by laster shoulder 38 accessored to the shart 18. r, the spacing between the sade in much as to limit the longitudinal of the bearing plate numbers on they more together to prevent person deformation of the column element \$3. Textons alternative means for preventing desage to the column element may also be employed. For example, plat or rings someted on the chaft may serve as stops, or the cover 48 provided with suitable commentations may be amployed for this purpose to limit longitudinal and/or lateral deflection of nolumns.

The columns of the column classes 43 may be extended eround the coart 10, which as shown here forces a portion of the body of the spring ferries, with made of the columns fitted in the reces 67. The solumns may be

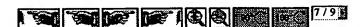
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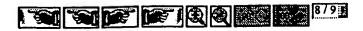




ritted closely together as shore, or may be spared around the race, with representers used between them to meistain the desired sparing. The runber of construction. For example, the elementary ratio of the column may be varied withly, say the column mails say be round, flat, fixed or hinged. The preferred construction is a thin, element column with considering from to move within the races shaped to the coveniers of the column sade, from to move within the races shaped to the coveniers of the column sade. Materials which may be actificationing employed for the column and or alloy steads, chronical section of the sales and locally steads, as passaged by because attained by providing and actifications extended properties. Typically, the individual columns are of long recompular cross-cention, with the clâth bring greater than the laichness, and arranged so that the wider face of the columns is normal to the almentur of the about. Thus, with surfacient compression loading, the columns backle, and tend shout the short 18.

For example, a group of columns 0.167-inch thick by 0.438-inch wife by 10.626-inches long, with the ands youwent, were febrioacted from A.f.S.I 4360 steel, quenched and draws at 573°F. Buth column was found to require a critical empression loading of \$50 pounds in order to bunkle the address. . After buckling, the selumns were found to have a very flot spring characteristio, as shown in Figure J, thereis Po is the critical bearing look and point unio the load and deflection at which the stress is the extreme fibers nt exceed the yield yount of the untertal. Theoretically, the shape of this spring characteristic curve is described by onces 04'ABC. Actually, Unis curve is described by OASC due to friction in the system. Poteta A and B not typical straing limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flaxing cycles are not applicated, a working stress just below the 30 yield point may be used, while with a great number of flaures, the working stress may be held to less than the undurance limit of the satisfied of some tion. In the above-mentioned tests, the intered surfaction was limited to





approximately one imph, at which the longitudinal deflortion was approximately 0.225 inches. From more deflection to the assumen deflection, the \$50-pound loading was found to be substantially constant.

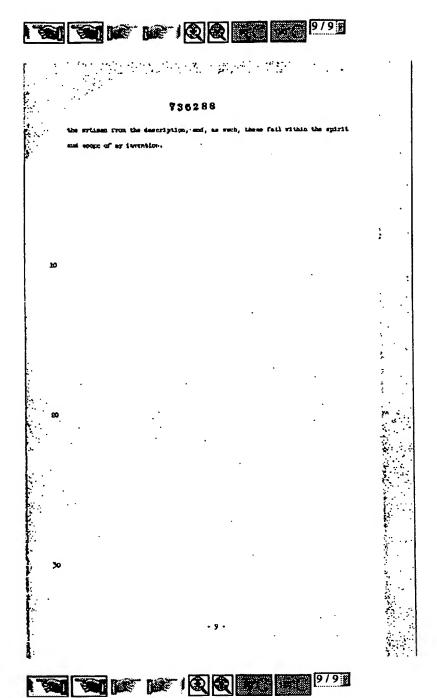
In enother test a spring device was built, as shows, employing 80 columns, each having a critical bushing load of 1250 pounds. The interal definition was limited between 0 and about 1.00 inches by empropriately positioning the stope. Once compressional inceing, the spring element bushled at exhibitality 25,000 pounds and from a longitudieal definition of 0.0k inshes (muchling) to stook 0.15 inches the load reasonal substantially at 25,000 pounds.

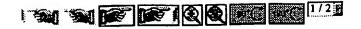
Or course, in dorigates a spring element as above it in advantagements obtain the greatest possible value of longitudinal definations for specified values of laboral deflection and artical bushing load, while unintending the atrees level to the columns at a safe lavel. The preferred columns, therefore, are laminated, as shown in Figures 18 and 2, with multiple flat annuary making to seek columns.

Do the operation of the above expending tool for setting a liner in well senion, the mede-up tool is invared into the well as sectioned above, with the area 22 in the retreated position. Then the tool is at the desired level, the well tabling is reduced. The friction member is capages with the wall of the easing and prevents thinkle in tron revolving. With several revolutions of the tables, hower shoulder 36 is moved appearably by differential server 39 to bunkle spring almost 37 which has a predeferminal critical bunkling lead. This lead is transmitted appearably against the lower one of supposer 36, and the tapered surface is suggest with the tapered surface on the Lands of the even 22 to urge the turns outputly with a substantially constant force proportional to the critical bushing load of the spring almost. Subsequently, the expending tool is passed through the liner to append it in the caping in the meaner described buretabelore.

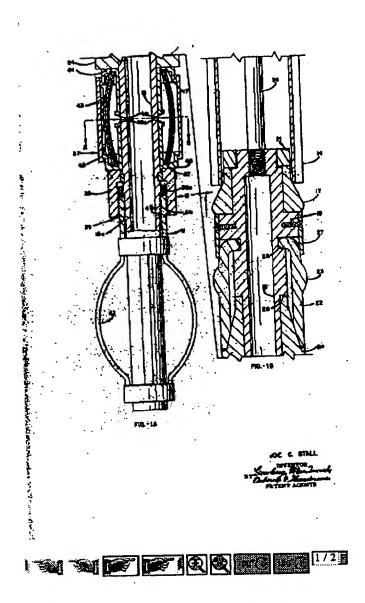
The foregring description of a preferred embalizant of my investion has been given for the purpose of examplification. It will be understood that various madifications in the detects of construction will become apparent to

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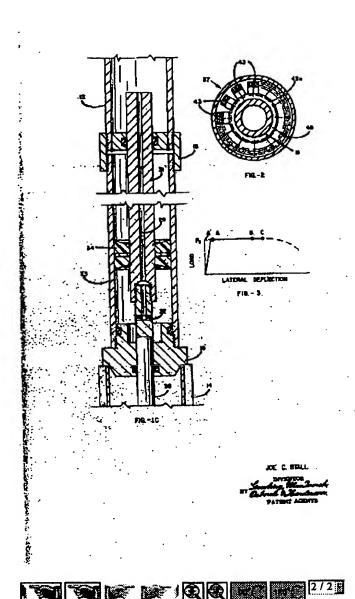




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